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BACTERIOPHAGE IN SOIL.*

BACTERIOPHAGE is an ultra-microbe or sub-microbe and, like most viruses, will pass through the pores of a filter fine enough to retain most kinds of bacteria. Like a virus, bacteriophage is particulate, and it is a matter of opinion whether either bacteriophage or virus is living or dead, a chemical compound or an organism. Bacteriophage is distinct from any enzyme or virus. All viruses are (by definition) pathogenic and, as bacteriophage (by definition) is lethal to one or several strains of bacteria, it can be said to be an agent producing necrosis or "disease" in bacteria. One microscopic particle of virus can produce a macroscopic spot of necrosis, involving many cells, in a large organism such as a plant. A single microscopic particle of phage can produce an equally visible spot of necrosis, involving many more (because smaller) cells, in a culture of bacteria growing as a thick film on a solid medium such as agar. This bacterial necrosis takes the form of practically complete solution of the bacterial cells, which are therefore said to be "lysed" or "phaged".

The best method of demonstrating the presence of bacteriophage is to make an even smear of a pure strain of bacteria, known to be susceptible to a given phage, over an agar plate supplied with appropriate nutrients. When growth has developed enough to be easily visible, a few drops of a filtrate containing phage are added. After incubation for a further short period there will be seen either a complete clearing of the growth over the whole surface where the phage-bearing liquid has been allowed to run, or else (if the dilution is higher) a few small circular clear areas. Each of the latter indicates one original particle of phage, which has multiplied at the expense of the bacteria near it, and has dissolved (lysed) them. Such lysed spots are either sterile, or, if viable bacteria can be recovered from them, such bacteria are phage-resistant mutants. The phage, however, is transmissible and can be propagated further. A filtrate prepared by passing a suspension of an affected culture through a bacteriological filter-candle will contain the phage, and the operation can be repeated *ad lib.* The clearing of an opaque suspension of susceptible bacteria in a liquid culture to which phage has been added is often spectacular and is completed in a few hours.

* From *Imperial Bureau of Soil Science, Soils and Fertilizers*, Vol. III, No. 1, pp. 1-2, 1940.

The nature and agricultural significance of phage are alike nebulous. The discovery and first investigations of true phage are usually attributed to d'Herelle (1917), but as a somewhat similar occurrence was described earlier by Twort, laboratory manifestations of phage are sometimes called the Twort-d'Herelle phenomenon. Both d'Herelle and Twort were animal pathologists, and for some years the investigation of phage was performed mainly on medical material, with special reference to the lysis of intestinal organisms such as those of the typhoid-dysentery group. Naturally, therapeutic applications suggested themselves, but little has been heard of them recently. Not long after 1917, phages capable of lysing some intestinal bacteria were found in manured soil and in some rivers, and were said to be especially prevalent in the latter near sources of sewage pollution.

Apart from these early demonstrations of colonic phages in soil and polluted waters, little attention was given to soil phages until their activity was suspected to be the cause of some failures of leguminous plants, especially lucerne. "Clover-sickness" in England has been imputed to a weakening action of phage on the nodule bacteria, but no evidence of any causal connection with phage has yet been adduced.

Work on the existence of phage attacking the nodule bacteria of lucerne has been done in Canada by Laird, and by others elsewhere. The best-known work is that of Demolon and Dunez in France, who have published a number of papers on the subject. The French authors claim to have established the presence of a very active form of phage in the soil of lucerne fields of three or four years' standing, that is to say, old enough to show "lucerne sickness" and to be invaded by grasses which have taken the place of dead lucerne plants. The phage is less easily demonstrable in young lucerne fields. When a sick soil was resown with seed inoculated with a phage-resistant strain of lucerne bacteria the take was excellent and the plants vigorous, whereas uninoculated seed and seed inoculated with active but not specifically phage-resistant bacteria gave rise to plants showing all the phenomena of sickness. No similar work has been done elsewhere. It will be seen that Demolon and Dunez have added a fresh requirement to the specification of bacteria intended for inoculation: the strain must be not merely effective in forming nodules and in fixing nitrogen, but must be resistant towards a particular (and possible local) strain of phage.

The investigation of bacteriophage in connection with leguminous plants has rather suffered from being largely confined to soil showing the symptoms of "fatigue" or sickness of a particular plant. It is not known how widely nodule bacteriophage is distributed in normal soil, but active phage may be more common in "healthy" soils than has been thought. In any case the question will arise as to what normally keeps the phages in check — or what favours their multiplication in an old crop. Katznelson in America has recently shown that several materials such as soil, peat, bentonite, &c., absorb or inactivate nodule-bacteriophage. Some of the field phenomena are not inconsistent with minor-element deficiency associated with a particular type of rooting, but crucial experiments which might establish the existence of a deficiency are lacking.

The matter is complicated by the existence of "abnormal" strains of nodule bacteria; some effects of such strains have been mistakenly attributed to bacteriophage: such are the avirulent strains which do not produce nodules and the ineffective ones which form nodules but do not fix much nitrogen. At least under laboratory conditions these may co-exist with each other, and some measure of apparently spontaneous transformation is also possible. In view of there being no record even of the fundamental fact whether many important extra-European legumes (*e.g.*, the Australian acacias) have nodules or not, it is evident that much further work will have to be done on the genesis of effective nodulation before the causes of some occurrences of legume sickness are ascertained. The matter is further complicated by the existence of non-transmissible bacterioclastic agents, such as that discovered in 1908 by Loew and Aso amongst pea nodule bacteria.

Bacteriophage has been compared to a seed-crystal bringing about crystallization in a super-saturated solution; it has also been thought to be a loose gene unprovided with any soma. In the face of such lack of comprehension of the nature of phage, no intelligent recommendations can be made for combating it agriculturally. The only suggestion that can be made if legume "sickness" manifests itself is the old one of rotation. Experimentally, very heavy manuring with animal dung or treatment on minor-element lines might be tried.

CITRUS MANURING IN CEYLON.

According to an article by A. W. R. Joachim in *Trop. Agriculturist*, 1939, 92: 216-19, an acre of citrus giving average yields removes from the soil per annum about 55 lb. nitrogen, 12 lb. phosphoric acid, 45 lb. potash, 85 lb. lime; thus citrus grown commercially requires to be fairly heavily manured and limed. An adequate supply of soil organic matter is also a necessity. Periodical liming of citrus plantations is necessary since citrus trees absorb large quantities of calcium, in fact calcium constitutes about one-third of the ash of healthy citrus trees. Lime deficiency is shown by chlorosis but chlorosis may also result from a number of other deficiencies and causes. For soils of average fertility beneficial results have been obtained from a fertilizer consisting of 3 parts sulphate of ammonia or nitrate of soda, 2 to 3 parts superphosphate or basic slag, 1 part sulphate of potash, applied annually a month before flowering at the rate of 4 to 10 lb. per bearing tree according to age and a month after fruit set another 1 or 2 lb. of sulphate of ammonia or nitrate of soda per tree. It is best applied dissolved in the irrigation water.

PRELIMINARY OBSERVATIONS ON THE REFRIGERATED GAS STORAGE OF GROS MICHEL BANANAS.

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(*Being a précis of a report now issued as Memoir No. 15 of the Low Temperature Research Station, Imperial College of Tropical Agriculture, Trinidad, B.W.I.*—Ed.)

Introduction.

The essential feature of banana transport is to delay the onset of ripening until the fruit is discharged from the holds at its destination. With relatively thin grades of Gros Michel fruit, *e.g.*, "$\frac{3}{4}$-full", this can usually be achieved by refrigeration alone during a voyage of 15 to 17 days. Heavier grades, however, tend to ripen during a similar transport period, and at the standard temperature for this variety, 53°F., chilling injuries develop by which both external appearance and eating quality are adversely affected; for such grades, therefore, gas storage might be used in conjunction with refrigeration to achieve the necessary retardation of ripening. Success along these lines would mean that a larger and possibly a better banana could be made available on the present markets or that the present grades could be transported from more distant centres of production. As an expedient of present value gas storage may also contribute towards the handling of fruit slightly affected by the secondary effects of Cercospora leaf disease which are known to induce premature ripening.

As an essential stage in preparation for the gas storage of bananas, research on respiration, transpiration and biochemical changes during the storage and ripening of different grades has been carried out so that in certain respects the metabolism of this fruit under standard conditions is now fairly well understood.

Observations on the gas storage of bananas have already been published by Kidd and West (1932, 1933) and by Gane (1936) of the Low Temperature Research Station, Cambridge. The data cited by them indicate that maximal effects in the retardation of ripening by CO_2 were obtained at low concentrations, *e.g.* 5 per cent. and that higher concentrations were deleterious in relation to gas concentration, duration of exposure and the condition of the fruit. Decreased concentrations of O_2 below the normal atmospheric concentration also caused retardation of ripening, harmful effects being experienced at 1 per cent. It may be noted that, of necessity, these experiments were based on imported fruit which had already undergone a period in refrigerated storage. Scurti (1938) has reported that ripening of bananas was retarded in an atmosphere of 2.5 per cent. O_2 at a temperature of 18°C. (64.4°F.), of 5 per cent. O_2 at 24°C. (75.2°F.), and of 10 per cent. O_2 at 32°C. (89.6°F.), the balance being N_2; normal ripening was resumed when the fruit was returned to air. A mixture of CO_2 and O_2 in N_2 also retarded ripening without damage to the fruit. According to this author (1937) the best results were obtained with 2.5 to 10 per cent. of both CO_2 and O_2 at temperatures below 18°C. (64.4°F.). Researches by Bottini (1934) are also concerned with the gas storage of bananas.

In the Memoir, of which this is a précis, an account is given of preliminary experiments on the gas storage of freshly harvested Gros Michel bananas at 53°F.

Experimental Approach.

As a preliminary approach to the many problems involved in the refrigerated gas storage of bananas, three types of experiment have been carried out. These include observations on:

(i) the retardation of ripening effected by different supplied gas mixtures;

(ii) the accumulation of CO_2 of respiration and depletion of O_2 in closed fruit containers (*a*) at tropical temperatures, (*b*) during cooling to 53°F. and (*c*) with precooled fruit at 53°F.;

(iii) the retardation of ripening in gas storage produced by restricted ventilation.

Where possible, accessory information has been obtained by observation of the trends of the internal concentrations of CO_2 and O_2, and of the CO_2 content of tissues, in individual fruits subjected to the same artificial atmospheres as the fruit used in storage trials.

The fruit selected ranged from "heavy $\frac{3}{4}$-full" to "full", *i.e.* from 155 to 200 grammes per finger, taken from 9 to 11 hand bunches. Such fruit would normally begin to ripen and develop chilling injury after 8 to 14 days at 53°F. in air.

Summary and Conclusions.

1. In "heavy $\frac{3}{4}$-full" fruit, rapidly cooled to 53°F. and held at that temperature for 20 days, gas mixtures containing 5 per cent. CO_2 and 7 to 12 per cent. O_2, supplied from cylinders, produced a notable retardation of ripening without injurious effects, the best results being obtained at the lower O_2 concentration. As compared with the control fruit in air, in which severe chilling injury was sustained, the gas stored fruit ripened to a good yellow colour; it showed no evidence of chilling, the palatability, bouquet and mealy "break" being those of normally ripened fruit.

2. In "heavy $\frac{3}{4}$-full" fruit, rapidly cooled to 53°F., a definite retardation of ripening was achieved by storage in O_2 concentrations of 6 and 12 per cent. (in N_2) supplied from cylinders. Ripening data, however, indicate that for heavy grades of fruit a reduction in O_2 concentration from 21 per cent. to 12 per cent. does not afford an adequate retardation of ripening during cold storage, whereas a reduction to 6 per cent. affords good retardation without injurious effects.

3. Conclusive evidence has been obtained that where some ripening has already taken place refrigerated gas storage does not retard further ripening sufficiently for practical purposes. Moreover, although the fruit may ripen to a product of good colour and texture, it tends to be "flavourless", astringent or lacking in normal banana flavour and bouquet. As in refrigerated storage, fruit showing incipient ripening or liable to commence ripening soon after harvesting, should not be accepted for refrigerated gas storage.

4. Gas mixtures containing 10 per cent. CO_2 and 8 to 12 per cent. O_2 failed to retard the ripening of "full" fruit (already showing incipient ripening) at 53°F., but no evidence of CO_2 injury, internal or external, was observed.

5. Observation of the internal concentrations of CO_2 and O_2 in fruits affords a valuable means of following ripening changes and also of assessing the normality of the changes observed. Accordingly, accessory information on the effect of artificial atmospheres on metabolism has been obtained by observation of the trends of the internal gas concentrations, and of the CO_2 content of tissues, in individual fruits.

6. As in other instances where gas storage has proved commercially feasible, it may be anticipated that, in arriving at a suitable artificial atmosphere for bananas, use will be made of the changes in atmospheric composition which result from respiratory processes, *i.e.* an increase in CO_2 and decrease in O_2. Experiments are described which throw light on this aspect and afford some indication of the procedure that may eventually find its place in commercial practice.

7. Whether at tropical temperatures or during rapid cooling to 53°F., the accumulation of CO_2 and depletion of O_2 take place rapidly in closed containers where the ratio: Volume of Fruit/Volume of Container is approximately .3 as on shipboard. It is shown, in fact, that refrigerated gas storage conditions could be achieved in the course of the first or second day from loading.

8. Under conditions of rapid cooling from tropical temperatures to 53°F., with CO_2 accumulation and O_2 depletion in closed containers, the respiration rate falls off rapidly from an initial value of 35 to 40 mg. kg. hr. to 8 to 10 mg. kg. hr. Under such refrigerated gas storage conditions the rate of liberation of CO_2 is only slightly affected by the composition of the atmosphere over a comparatively wide range of CO_2 and O_2 concentrations, this being indicative of a balanced relationship between the content of CO_2 in the fruit tissues and its concentration in the surrounding atmosphere.

9. In fruit subjected to gas storage conditions involving a concentration of CO_2 higher than that of normal air, there is an increase in the CO_2 content of the tissues, but, on returning such fruit to air, the CO_2 escapes rapidly. Data are given showing that in fruit which had been subjected to an atmosphere containing 17.75 per cent. CO_2, the normal CO_2 content was reached after approximately 30 hours.

10. A summary is given of observations on respiration rates and of rates of accumulation of CO_2 and depletion of O_2 in closed containers under different conditions. In the light of these observations certain theoretical and practical aspects of gas storage are considered. The effects, on the composition of the storage atmosphere, of removing excess CO_2 by ventilation and by chemical treatment are compared: it is shown that whereas the former procedure tends to increase the concentration of O_2, the latter tends to decrease it, but that by a suitable combination of the two methods it should be possible to keep the artificial atmosphere at approximately the constant composition desired. It may, in fact, be anticipated that in commercial practice the gas storage of bananas, as of other fruits, will be achieved by a system of restricted ventilation in conjunction with the removal of excess of CO_2 by chemical means. In systems of this kind, the part played by physiologically active volatile substances, liberated from the fruit and known to accelerate ripening, may be of critical importance.

11. Several experiments are described in which gas storage at 53°F. was achieved by the method of restricted ventilation, *i.e.* by drawing air slowly (or intermittently) through containers charged with fruit. At suitably slow rates of flow, artificial atmospheres having a composition of 6 per cent. CO_2 and 14.5 per cent. O_2 were obtained; the difficulty of obtaining sufficiently low concentrations of O_2 (with CO_2 at approximately 5 per cent. concentration) by restricted ventilation alone becomes apparent in such experiments.

12. In the artificial atmosphere quoted in *para.* 11 above, "heavy ¾-full" fruit was satisfactorily held at 53°F. for 20 days. On removal to air in the ripening room at 68°F., the fruit was still quite green, and subsequently ripened to a product of good appearance, texture, flavour and bouquet, quite free from any trace of chilling. The control fruit, by contrast, underwent some ripening during cold storage and was severely chilled. Lastly, it is to be noted that such restricted ventilation was not attended by ripening induced by volatile substances, any such effect being suppressed or offset by the prevailing gas storage conditions. It was also noted that no harmful effects resulted from occasional brief exposures of the fruit to CO_2 concentrations as high as 10 per cent. That artificial atmospheres, which would be advantageous in banana storage, can be obtained by restricted ventilation alone is evident from the data submitted: the limitation of such a procedure resides in the difficulty of obtaining sufficiently low concentrations of O_2 while avoiding undesirably high concentrations of CO_2.

13. In an experiment on the gas storage of "full" fruit by restricted ventilation, the presence of fingers showing incipient ripening caused an acceleration of ripening in the aggregate of fruit in the container. This may be attributed to the accumulation of activating volatile substances

liberated from the early ripening fruits. Although the fruit ripened during cold storage external symptoms of chilling were entirely absent. In the control lot, by contrast, where volatile substances were kept at a low concentration by the high rate of ventilation adopted, ripening was considerably less advanced at the end of the cold storage period than in the gas stored fruit but the fruit was chilled. These observations again emphasise the finding that fruit showing incipient ripening (*i.e.* mature "full" fruit at harvesting) is just as unsuitable for refrigerated gas storage as it is for refrigerated storage. Occasional bunches which have ripened during commercial gas storage should be rejected on being removed from the holds as their poor flavour, which would not be anticipated from their appearance, would be harmful to the Trade.

14. Evidence of "gas injury" was observed in fruit which had occasionally been subjected to high concentrations of CO_2 and low concentrations of O_2. The skin of affected fruits became profusely freckled with minute, non-sunken, greyish brown spots, this being accompanied by a slight greyish darkening of the skin.

15. The application of the results so far obtained to practical conditions and an outline of future investigations are briefly considered.

16. Collectively, the data obtained indicate that by using rapid cooling in conjunction with artificial atmospheres containing approximately 5 per cent. CO_2 and 5 to 7 per cent. O_2 it should be possible to effect the overseas transport, during a voyage period of at least 16 days, of a grade of Gros Michel fruit considerably heavier than "$\frac{3}{4}$-full" and even surpassing "heavy $\frac{3}{4}$-full" from certain environments.

BIOLOGICAL ASPECTS OF SOIL FERTILITY.

An interesting case of the predominating influence of a biological factor in controlling the fertility of a soil is described by Professor W. Neilson Jones in *Nature*, Vol. CXLV, p. 411, 1940. The particular soil in question supports coniferous forest at Wareham in Dorset, England. Certain areas in the Wareham Forest show marked infertility which cannot be attributed merely to lack of nutrient salts in the soil, nor to excessive soil acidity, nor to any other simple or obvious cause. The peculiar infertility, however, is readily counteracted by the application of certain organic composts, but the exceptionally good growth attained by this means cannot be accounted for by the available nutrients contained in the manure.

The hypothesis was therefore advanced that the local infertility is "due to toxic residues formed during decomposition of organic detritus by micro-organisms", and that "the effect of the compost is to provide a substrate which, by altering the serial activities of the different soil micro-organisms, modifies the chain of reactions constituting humus decomposition, with the result that the final residues, instead of being toxic, are favourable to the growth of the trees (as well as) to the mycelial growth of the fungi associated with them as mycorrhiza-formers, and to the establishment and free-functioning of a normal balanced mycorrhizal relationship".

The experimental methods and observations advanced to test this hypothesis in the present case were :—

(1) An artificial nutrient agar medium, which readily develops fungous mycelia by infection from the air, failed to do so when spread as a thin layer over the Wareham infertile soil. This suggests that some toxic substance diffuses from the soil into the medium, and so inhibits mycelial growth.

(2) Treatment of the soil by heating or alcohol, removed the inhibitory property, suggesting that this is a product of some sort of micro-biological activity.

(3) The toxicity also disappeared when the soil was mixed with compost manure, indicating that conditions unfavourable to the toxic organism are thereby induced.

(4) The toxicity of the infertile soil was regained within ten days after partial sterilization, which again points to a soil organism as the toxic-forming agent.

(5) The infertile soil failed to bring about the decomposition of cellulosic substances deliberately buried in it, whereas decomposition was rapid in the normal fertile soil, or infertile soil to which compost had been added. The inhibitory action thus extends to the fungi responsible for cellulose decomposition.

These striking experimental results lead to the inevitable conclusion that "Wareham soil, and soils like it, contain a 'toxin' which inhibits growth of fungi, such as air-borne moulds and mildews, (as well as) some of the mycorrhiza-formers, and those responsible for cellulose decomposition". This toxin apparently is a product of the metabolic activity of some soil organism absent from normal fertile soils, though presumably involved in humus decomposition.

Doubtless many similar cases could be found of tropical soils that have been planted to crops such as cacao, coffee, citrus and certain forest trees failing to produce high yields through the operation of some harmful biological factor, as in the case of the Wareham forest soil described above. By means of detailed ecological investigations, in which all the growth factors involved in crop production are severally examined and assessed, it should be possible to identify this peculiar cause of infertility, and subsequently to initiate corrective measures. Certain instances of the conspicuous success that follows the use of organic manures, including pen manures and composts, may indeed be attributed to their biological, rather than their nutritional, action.

F. H.

PHYSICAL PROPERTIES OF SOILS THAT AFFECT PLANT NUTRITION.

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In a paper bearing the above title, R. E. Stephenson and C. E. Schuster of the Oregon Agricultural Experiment Station and the U.S. Bureau of Plant Industry, have discussed data obtained in regard to the water and air relationships of some orchard soils in Oregon (1). Although numerous theoretical researches have been made on the physical properties of soils, ecological investigations and soil surveys often involve the assessment of no other physical factors than texture. Stephenson and Schuster's results exemplify the importance of other measurable soil properties, such as moisture capacity, availability of water, permeability and aeration, in determining the performance of tree crops. The methods of study used therefore deserve attention, though several modifications in technique may be suggested.

The supply of water and mineral nutrients to a plant depends upon the nature and extent of its roots, and upon the quantities of water and available nutrients in the soil. The water supply is recognised as being of primary importance in the tropics, and in order to study its effects on crop growth, it is necessary to know what portion of the soil moisture can be used by roots. The actual quantity of moisture in the soil may be limited by its capacity to store water against the force of gravity, or by its permeability, which controls the rate at which it can absorb water at the surface or allow it to percolate to deeper layers.

Adequate aeration seems to be essential for the functioning of roots as well as for their growth and consequent utilisation of the soil material. Another factor affecting the distribution of roots, which it is not easy to assess nor to distinguish from inadequacy of aeration, is the mechanical resistance to root penetration. Stephenson and Schuster point out that the diameter of growing root-tips probably lies between 0.1 and 0.5 mm.; they are therefore much larger than particles of silt and clay. The aggregation of heavy soils into grains of the size of sand is essential in order to permit roots to penetrate. Thus, the few roots found in heavy horizons are stated often to be tightly held and more or less compressed or squeezed out of shape.

Methods of Study.

(1) *Available Moisture.*

The quantity of available moisture in any portion of soil is estimated by subtracting the wilting coefficient from the gross moisture content. The wilting coefficient (W) is defined as "the moisture content of the soil (expressed as a percentage of the oven-dry weight) at the time when the leaves of the plants growing in that soil first reach a stage of wilting from which they cannot recover in an approximately saturated atmosphere without the addition of water to the soil". This is the condition of permanent wilting. Stephenson and Schuster determined wilting co-efficients by the direct method of growing sunflower plants in pots of moist soil waxed over to prevent loss of moisture except by transpiration, and noting the stage when permanent wilting occurred. The procedure may, however, be regarded as unnecessarily laborious.

Botelho da Costa (2) has produced a critical survey of investigations on wilting coefficients, and has shown that no value can be attached to indirect estimates of this soil constant arrived at by the assumption of definite relationships with other soil-moisture constants, such as the hygroscopic coefficient, maximum water-retaining capacity or water equivalent. On the other hand, he has found (3) that very reliable results are obtained by assuming that W is equal to the moisture content at a pF value of 4.2 on the drying curve, except when the soils are saline. pF values in this region can be determined with certainty by means of the depression of the freezing-point of the soil water, and Schofield and da Costa (4) have described suitable technique for the purpose. The determination of wilting coefficients by the freezing-point method could certainly be carried out on a large scale.

(2) *Specific Gravity and Porosity.*

A true measure of the aeration of a soil is not easy to define, for it should include both the composition of the gas in the interstitial spaces and the freedom of movement which that gas is afforded. Stephenson and Schuster took as a practical index the percentage by volume of air space in the soil, which is the difference between the total porosity and the percentage volume occupied by water. The total porosity is calculated from the real and the apparent specific gravity. Thus if d_1 and d_2 are the real and apparent specific gravity respectively, the pore space or total porosity (S) is equal to

$$\frac{d_1 - d_2}{d_1} \times 100 \text{ per cent.}$$

The volume occupied by water is the percentage by weight multiplied by d_2.

Post-hole diggers were found to be useful implements for obtaining soil samples to a depth of ten feet. Fairly large chunks of soil in an undisturbed state were weighed, and the volume determined by displacement of light oil in a graduated cylinder. In making measurements on some sandy soils, a metal cylinder of known volume was pressed in, and the sample levelled off at the ends. A common procedure for estimating the apparent specific gravity involves cutting undisturbed lumps of soil, coating them with wax, and determining the volume by

displacement of water. Owing to the shrinkage and cracking which occur when heavy soils dry out, it is necessary to carry out specific gravity determinations when such soils are wet. Crumbly surface layers and soils which have been recently broken up by tillage have to be dealt with by the use of a metal cylinder, preferably a fairly large one. In all cases, it is necessary to avoid compacting the sample.

The true specific gravity of the solid matter is determined in the familiar way, using a small graduated flask or density bottle, and finding the relative weights of water and a mixture of soil and water.

(3) *Capillary Porosity.*

One of the factors determining the actual moisture content is the drainage. When a soil is saturated, part of the moisture is generally free to drain away under the influence of gravity; the amount which is able to do so corresponds to the percentage of the pore space which consists of channels greater than approximately 0.01 mm. in diameter. The remainder of the pore space is commonly termed the capillary porosity, presumably consisting of pores of capillary size.

Clay is no longer regarded as microscopic sand with spaces of very small diameter between the particles, in which water is retained by surface-tension forces. Some of the capillary water passes into the elastic lattice structure of the ultimate clay particles, causing them to swell, whilst some of it forms adherent films and water-wedges over and between the particles.

Stephenson and Schuster measured the capillary porosity by the volume occupied by water a few days after saturation by rain (*i.e.* the field moisture capacity on the basis of volume). Whatever the nature of the capillary porosity may be, it is important in two ways:—(*a*) the difference between the capillary porosity and the volume of water corresponding to the wilting coefficient measures the capacity of the soil to store available water after a rainy season or after irrigation, and (*b*) the difference between the total and the capillary pore space (*i.e.* the non-capillary space) indicates the worst state of aeration which is liable to occur.

The field moisture capacity is a rather indefinite quantity, because conditions of equilibrium develop slowly in soils; it must also be affected by topography and by the construction of drains. It would therefore be advantageous for some purposes to make a standardised measurement of the capillary porosity, which is a soil property independent of drains and topography. The moisture equivalent is known to serve very well for this measurement, for it is correlated fairly closely with the field capacity. The moisture equivalent is determined by centrifuging in a special apparatus a suspension of the soil under a force corresponding to 1,000 times gravity; it is therefore the moisture content at a pF value of 3.0 on the drying curve.

Equipment for the determination of moisture equivalents is beyond the resources of many soil laboratories; hence a simpler means of determining the capillary porosity may be suggested from the possibility that Hardy's Index of Texture (5) may be regarded as a measure of the capillary moisture. The index of texture multiplied by the apparent specific gravity of the soil is then equal to the capillary porosity. The index of texture does not seem to have been adopted outside the Imperial College of Tropical Agriculture, and unfortunately no direct comparisons with the moisture equivalent are available, but Bodman and Perry (6) and Prescott and Poole (7) have compared the moisture equivalent with the sticky-point, and found fairly close correlations. According to the first-named authors, the two values are nearly equal throughout the range from sands to clays, while according to the latter, the extrapolated value of the sticky-point appears to be between 15 and 20 per cent. when the moisture equivalent is zero. Since in the original definition, the index of texture is defined as the sticky-point moisture content minus one-fifth of the percentage of sand, a fairly close concordance between the moisture equivalent and the index of texture can be inferred.

The capillary porosity, as measured by means of the moisture equivalent or the index of texture, may exceed the total porosity, and then the field moisture capacity is obviously determined by the total porosity.

(4) *Shrinkage, Cracking and Soil Structure.*

The development of a granular structure increases the non-capillary porosity and consequently the aeration of a soil, but it has other effects also, such as facilitating the penetration of roots and increasing the permeability of the soil to water. Since the penetrability and permeability are not completely assessed in terms of the non-capillary porosity, it would be desirable to study the granulation of the soil by a direct means.

Apart from the special advantages of a crumb structure which persists even when the soil is saturated with water, Stephenson and Schuster attached importance to the shrinkage and cracking of all clay soils. Roots are able to grow down the cracks and exploit the lower layers of soil, even though they may remain in a dormant state during part of the year. Water also percolates rapidly through the soil cracks until they become sealed up by the swelling of the clay.

The amount of shrinkage was estimated by the simple means of measuring the volume (by displacement of oil) of weighed coherent lumps of soil taken when dry and when wet. For example a lump of dry clay, 100 c.c. in volume, might weigh 192 g., while an equal-sized lump of wet clay might weigh only 142 g. after drying; the shrinkage (by volume) would thus be

$$100\left(1-\frac{142}{192}\right), \text{ or } 26 \text{ per cent.}$$

Values obtained in this way were in agreement with those calculated from measurements of linear shrinkage.

Permeability of Soil to Water.—The fundamental laws governing the movement of water through the soil are complex and are very imperfectly understood. At the same time, there appears to be a notable dearth of relevant data obtained from field studies. It is obvious that the looser the soil and the coarser its texture, the more readily does water percolate through it; but it would be desirable to have a measurable quantity determining the rate of absorption of water, especially in the case of fine-textured soils in which this factor may conceivably exceed all others in importance, as far as perennial crops are concerned.

Carman (8) has recently published a theoretical discussion of the problem of the rate of movement of water through saturated homogeneous sands, soils and clays. His equations (which involve particle size, porosity, and hygroscopicity) can only be of limited application because of the heterogeneity of many soils, and because the absorption of water consists only partially of movement through a saturated medium. At the present time, an empirical approach to the subject by means of field studies would be the most desirable.

Evaporation of Moisture.—Reduction of the rate of evaporation of moisture from soil surfaces by means of shading and mulching is particularly stressed in tropical agriculture. Keen (9) has shown that many of the older views on the water relationships of soils were erroneous, and states that the drying out of a soil is to be regarded almost entirely as a process of evaporation *in situ*, followed by diffusion of water vapour through the pores of the soil into the atmosphere above. The process of diffusion is more rapid in loose and porous soils, and is probably not affected by mulching. The rate of evaporation at a certain depth depends mainly on the temperature, and this is controlled chiefly by the extent of exposure of the soil surface to the rays of the sun, but also, in a minor way, by the conductivity of the soil to heat.

Examples of Numerical Results.

Measurements of Pore Space.

The true specific gravity of soils does not vary greatly, nearly all values falling between 2.40 and 2.75. In soils of the same general type, variations are generally correlated with the content of organic matter which lowers the true specific gravity. The pore space of undisturbed soils ranges from about 40 to 60 per cent., but very low values may occur as a result of downward movement and deposition of colloids, such as iron oxide. Table 1 illustrates the arithmetical relationships between true and apparent specific gravity and pore space.

This table shows that in order to estimate percentage pore space accurately to the nearest whole number, the value for the true specific gravity need only be correct to less than 0.05. Consequently, work can be reduced by mixing together suitable samples for its determination. For example, in the case of a fairly uniform profile, all the samples taken below the humic layer might be mixed together and a single determination made on the composite material.

Table 1.

Apparent Specific Gravity (d_2).	True Specific Gravity (d_1).		
	2.40	**2.55**	**2.70**
	Pore Space (per cent.)		
1.00	58.4	60.8	63.0
1.10	54.2	56.9	59.3
1.20	50.0	53.0	55.5
1.30	45.8	49.0	51.8
1.40	41.7	45.1	48.1
1.50	37.5	41.2	44.4
1.60	33.3	37.3	40.7
1.70	29.2	33.3	37.0

The free air-space of undisturbed soils is often less than ten per cent., and it is desirable for this reason to know the total porosity fairly accurately.

Characteristics of Two Oregon Soils.

The data in Table 2 recorded by Stephenson and Schuster contrast the ideal moisture and air relationships of the Newberg Loam with the unfavourable properties of the very heavy Sites Clay.

Other Data on Aeration.

Boynton and Reuther (10) have devised a method for withdrawing gas samples from dense subsoils, and obtained some important results on the seasonal variation of the oxygen and carbon dioxide content of three soils supporting apple orchards. The soils were; (1) a highly-productive sandy loam soil, uniform to below the 6 ft. depth, with non-capillary pore space approximately 16 per cent., (2) a silty clay loam with productivity above the average, also uniform, and with non-capillary pore space between six and eight per cent.; (3) a silty clay soil on which apple trees were short-lived and had a low level of productivity, the non-capillary pore space being less than in the second soil above four feet, and then decreasing to about one per cent.

The silty clay soil (No. 3) contained no gas at the 6 ft. depth during half the year; as it dried out, the oxygen content of gas at this depth rose from 0.1 to a maximum of 11.5 per cent. Even at a depth of two feet, the oxygen content was very low during part of the year in this soil. On the other hand, the oxygen content at six feet in the sandy loam (No. 1) only varied from about 14.5 to about 20 per cent. The silty clay loam (No. 2) was intermediate between the other two soils, but there was no gas at six feet for four months of the year, after which the gas content consisted only of nitrogen and carbon

Table 2.

Horizon	Silt and clay (0.02-0.0 mm.)		Water at Field Capacity (Capillary space)		Air Space (non-capillary)		Wilting Coefficient		Available Water	
Lower depth in feet	Per cent.		Per cent. by volume		Per cent. by volume		Per cent. by weight		Per cent. by volume	
	Sites	*Newberg*	*Sites*	*Newberg*	*Sites*	*Newberg*	*Sites*	*Newberg*	*Sites*	*Newberg*†
1 ...	65	55	45*	41	9*	14	22	16	15*	22
2 ...	68	43	43	39	14	18	23	14	13	23
3 ...	71	33	48	40	9	17	26	16	13	23
4 ...	70	53	52	41	6	16	30	15	12	25
5 ...	82	51	58	41	0	17	32	16	18	23
6 ...	70	41	65	42	−2	16	44	13	7	27
7 ...	70	27	—	36	—	20	—	—	—	—
8 ...	64	34	—	40	—	17	—	—	—	—

* Average of values quoted for the 1st and 2nd 6-inch layers.

† Values given by Stephenson and Schuster on a weight basis have been multiplied by the ratio of capillary pore volume to field moisture capacity (by weight).

dioxide for two months, and then the oxygen content rose to a maximum of 16.5 per cent. There was a fair amount of oxygen at the two feet depth throughout the year in this soil.

The distribution of roots in the three soils described was decided mainly by the oxygen supply. Boynton and Reuther recognised that the composition of the gas gave an incomplete picture of the oxygen-supplying ability of the soil, but allowance for the readiness of diffusion of oxygen from the soil to the root would presumably only increase the distinctions indicated by the static measurements. The results therefore show that the non-capillary pore space is the chief factor which determines the state of aeration of a soil in the field.

Root Distribution and Consumption of Available Moisture.

Stephenson and Schuster found that marked differences in the distribution of roots occurred below the top three feet and, since the concentrations of nutrients were very low at such depths, it was believed that the function of deeply-penetrating roots was almost solely that of water absorption. The distribution of roots at the lower depths was correlated with the character of the aeration, which was classified in the following way: in horizons with 10 to 20 per cent. of air space at field moisture capacity, it was called "good"; in those with 6 to 12 per cent., "average", and in those with less than five or six per cent. "poor".

The data quoted above for Sites Clay show fair amounts of available water between two and six feet, but only half of this was actually used during a season in which Walnut trees on this soil were suffering from lack of water. This was because there were insufficient roots in the lower layers to absorb the water, which also could not move by any process of capillary uplift into the root zone. It was suggested that, if the texture became sandier with increasing depth, the smaller capillaries of the heavier surface soil would be able to draw water from the larger capillaries of the deep soil, so long as it were not too sandy.

A general conclusion from Stephenson and Schuster's investigation was that, when transpiration rates are high, trees may suffer from lack of moisture, even though the moisture content of the soil is far above the wilting coefficient, in those cases where their root systems are not extensive enough to make full use of the available soil moisture. Temporary water shortage in the tree may exert serious effects on the development of the crop. Investigations on pears are quoted in this respect (11).

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The Editor requests that any subscriber who fails to receive *Tropical Agriculture* regularly should communicate with him immediately in order that the matter may be rectified.

EMPIRE COTTON GROWING POLICY.*

THE Empire Cotton Growing Corporation was founded at the end of the last Great War to foster cotton growing in the Empire, apart from India, which has its own special organization.

During the twenty odd years that have elapsed much has been done by research, experiment and propaganda to forward the work, and considerable experience has been obtained. Real progress has been achieved in some areas, whilst in others somewhat disappointing results have been noted.

It has now been decided that the time is opportune to take stock of the position and to review the policy of the Corporation in the light of the experience gained during this period. The matter has been submitted to the Scientific Advisory Committee of the Empire Cotton Growing Corporation for consideration and it has been asked to make recommendations. As a preliminary step the Governments of the various cotton-growing Colonies have been addressed with the object of ascertaining their views on future policy and at the same time the work of the various experimental stations which are maintained or supported by the Corporation has been examined. The work of these experimental stations has been reviewed by Mr. W. Nowell, who is a member of the Advisory Committee and the following extract from his Review* which follows gives an account of some of the problems involved and of the present position of cotton growing in the African Colonies, which is bound to have an important effect on the line of policy that will eventually be adopted.

Mr. Nowell in his Review states :—

The inclusion in many of this year's progress reports of explanatory introductions by the responsible Directors and senior officers, and of summaries of work provided by the officers concerned, covers much of the ground previously occupied in this Review. This leaves room for a discussion of the general lines of development in Africa to which, it is submitted, consideration of the programmes of present and future research should be referred, as well as for comment on those features of the year's work which have reached a stage which gives them interest for the general reader, to whom this Review is addressed.

The expansion of Empire cotton production has, in practice, depended upon progress in the African continent, and it is to Africa that we must look for its maintenance and for any further material increase. The outstanding fact about African production is that south of the Gezira it has developed almost exclusively as a peasant industry.

The introduction to the Barberton report opens with the admission that the commercial cotton crop of South Africa (entirely a European farmers' crop) has made no headway since the drastic reduction that followed the fall in prices of 1929-31, and states that no large-scale expansion is likely unless the price remains for several years at something over 7*d.* a lb. Similarly the report from Gatooma is prefaced with the statement that there were very few commercial growers of cotton in Southern Rhodesia last year owing to the low price prevailing at planting time. When cotton drops below 6*d.* the farmers lose interest in the crop, not because it does not pay, but on account of the superior attraction of crops sustained by such artificial measures as bounties, preferences and controls.

To illustrate further the same tendency, it may be noted that in Nyasaland European production fell from 1,920 cwt. of lint in 1936 to 843 cwt. in 1938; in Tanganyika Territory non-native production (mainly as a catch crop in young sisal) amounted to 4,255 bales in 1938 (about ten per cent. of the crop), which represents a considerable falling off. "Until prices improve it is unlikely that there will be any appreciable increase". Cotton production in Uganda, Nigeria, and Kenya is entirely a native industry.

Hardly any development of native cotton-growing has taken place in South Africa and Southern Rhodesia, though there is said to be room for an appreciable amount to be grown in suitable areas of both Swaziland and Natal, and there is evidence of present interest on the part of the Native Affairs Departments in Natal and in Southern Rhodesia. Observation plots in the native areas of Natal are recorded as having given very good crops, and the selection of further trial sites representative of large tracts of native cultivation is projected. In Swaziland cotton was extended to the native areas in 1933 and promised well, but poor seasons and low prices restricted development as alternative sources of revenue became increasingly available. Native agricultural methods consist almost entirely of continuous cereal growing, and there is room for cotton to play an important part in an improved system of rotation farming. In Southern Rhodesia during the year under report a government officer was seconded for propaganda in the Native Reserves to encourage cotton-growing, with what success remains to be seen. Here, as elsewhere in Southern Africa, the proximity of many sources of wage-earning employment weakens the economic motive which is so effective further north. Even in the latter regions results are not attained without a great deal of effort on the part of agricultural and administrative officers, and in countries where agriculture is primarily organised to meet the needs of European farming there is not sufficient interest or energy to spare for this purpose.

Unless some radical change results from the War it is evident that the maintenance of cotton-growing in British Africa is wholly bound up with native agriculture. Recognition of this must be the basis of all programmes of investigation and development. And behind all

* Extracted from *A Review of the Work of the Experiment Stations*, Season 1938-39 by W. Nowell, C.M.G., C.B.E., Empire Cotton Growing Corporation, 1940.

experiment and research on individual crops, such as cotton, there is the need for a body of fundamental knowledge concerning native systems of agriculture and land tenure, especially in relation to the maintenance of soil fertility, on which the permanence of export industries depends. Under the stimulus of "colonial development" little regard has been had to these matters, until quite recently, by those with power to control policy. Present prosperity has been accepted or sought without much question as to its permanence.

Previous to the development under European influence of export crops the general system of African native agriculture was based on communal land tenure, the community being the local tribe or clan. There was, as a rule, ample land available but there was no incentive for the individual to clear and cultivate more than would normally suffice for the subsistence of himself and his dependants, nor any need for labour beyond that which he and his family could supply. The period of occupation of a plot was determined by continuance of use: when the initial fertility was running out and weeds of cultivation were gaining the upper hand, it was abandoned and reverted to the common pool. With rare exceptions no fertilisers were used, but regeneration slowly ensued under cover of the invading native vegetation, and after a period of years, varying widely in relation to the local factors of soil and climate, the cycle could be repeated.

This is the system which is still generally followed for the production of subsistence crops, and it is on to this system, and still following the same agricultural methods, that the production of export crops has been grafted. The most obvious result, where this develops on a considerable scale, is the occupation of more land. The most striking examples of this are to be found in Uganda, where the acreage occupied by one only of the export crops—cotton—increased from 50,000 in 1912-13 to one and three-quarter millions in 1937-38, and in the Gold Coast, where figures of acreage are lacking, but the exports of native-grown cocoa rose from 12 tons in 1893 to 300,000 tons in 1936-37.

Changes are taking place, very irregularly according to local circumstances, in methods of land tenure: some evolutionary, in response to the new feature of cash crops, some political, and in some places there is even a tendency towards individual ownership. The impulse behind these changes is not, however, so strong in the case of an annual crop like cotton as with permanent crops, such as cacao or coffee. Their main importance will come in the future, when the relative efficiency of collective and individual ownership has to be considered.

The question of to-day is the strain on the land due to the greatly increased acreage occupied. Formerly, food production was limited by local needs; there was usually, under the conditions of population prevailing, plenty of land to spare, and economy of effort was a strong incentive to allow ample time for regeneration. There is no such narrow limit to an export crop with a world market. The simplicity of native standards of living checks the enterprise of the individual producer, but the effect of this is offset by the great numbers of those whose monetary requirements, though modest, are pressing. In the great majority of cases the particular cash crop suited to the locality offers the only means of meeting these requirements, and it is for this reason that economic considerations, in the ordinary sense of production for profit, have little relevance. Land is mostly either free or subject to trivial charges, subsistence apart from small luxuries and a very few necessities, is provided by food crops, and the cotton or other cash crop therefore represents only an extra amount of family labour and attention, on which no definite value can be set. The only standard of price is based on previous experience: a constant low level excites no comment, a fall in price causes discontent and tends to relaxation of effort, but in the circumstances as set out it rarely leads to cessation of production. A bad season produces no farming losses to be carried forward to another year.

The expansion of production under these conditions may be limited by natural factors: unsuitable soils, uncertain rainfall, or the incidence of pests and diseases; but the flood which rises when these checks are weak or absent is shown by the figures quoted above.

In any district where an export crop gets a strong hold the primitive system of agriculture must sooner or later break down, although this may be long delayed by the existence of great original reserves of land. For every acre under cultivation there must be several more undergoing regeneration. The use of more and more of the land for cash crops brings about the reduction of the resting period until it is no longer effective for its purpose, and cumulative degeneration sets in.

This is the problem which is being faced by the Departments of Agriculture, and provides the reason for their present active interest in mixed farming and other modified systems of peasant holdings. It justifies the view that in the work of the African experiment stations fundamental importance should be attached to those experiments which have as their object the improvement of agricultural practice in relation to the soil. Not one, but many new systems of agriculture require to be developed to suit the widely varying circumstances.

Continuing his review Mr. Nowell describes the following agricultural practices.

Fallow Planting and Green Manuring.

Over a large part of Western Uganda the dominant element in the natural vegetation is elephant grass (*Pennisetum purpureum*), and for this area the answer to the problem of the maintenance of fertility would appear to be supplied by the experiments at Bukalasa which have demonstrated that a three-year fallow under elephant grass, planted after a three-year period of cropping, restores and even improves fertility

The grass requires a rather abundant rainfall to make luxuriant growth, which restricts the application of the method to the wetter districts.

An approach to a similar practice is seen in the main rotation practised at Domira Bay (Nyasaland) where pigeon pea occupies the last two years of a six-year rotation to provide a resting period for the soil.

At Bukalasa the digging in of sunn hemp as green manure at varying periods before planting cotton produced no increase in yield. There was a similar experience at Uzinza, in the Tanganyika area bordering on the eastern shore of Lake Victoria, where it has been found that little effect can be expected from green manuring with sunn hemp in dry years. In the same area a local tribe who have long practised green manuring interplant their grain crops with a legume for this purpose. In a trial of this system made with five of the most likely legumes, only one, the native *Tephrosia vogellii* gave a significant increase. At the Morogoro Station the green manuring experiment with sunn hemp has shown that its use improves the fertility of the land for the first two years after the crop is dug in; the effect has disappeared by the third year.

The prospect of maintaining fertility by the use of green manures has great attractions, especially where conditions favour neither the keeping of animals for the provision of farmyard manure nor the making of compost. The notorious unreliability of the results, and the reluctance of native cultivators (save in a few special instances where the practice is traditional) to raise a crop which gives no direct return do not, however, encourage hopes of widespread adoption. It is not easy to understand why the direction taken by the Bukalasa work on elephant grass is not more generally followed, using selections from the wide range of plants available to fit the differences in soils and climate. In such trials legumes will have their part, though it is to be hoped with no such exclusiveness as is commonly the case in experiments with green manure. It should be easier to lead the native on with an adaptation of his own method of regeneration than to induce him to move at one stride into a system of continuous cultivation. Where the limitations mentioned above exist, the latter alternative, however desirable, is simply not available.

Farmyard Manure.

The permanent manurial trial at Serere, which has now completed its second cycle since it was laid out in 1933, has produced results which do not encourage the expectation that continuous cultivation can be maintained, on the type of soil concerned, by orthodox farming methods. During a four-course rotation, in which cotton is alternated with finger millet and groundnuts, three green manure crops are included, and farmyard manure up to 30 tons to the acre is applied at three-year intervals. While the cotton crops have shown continuous benefit, the other crops have not responded in any way, and the soil on all the plots has the appearance of being worked out and badly eroded. It should be noted that the conditions are those of the "short-grass region" of Uganda, as distinguished from the "elephant grass region" represented by Bukalasa.

This experience contrasts with the results obtained so far in a Swaziland experiment which has been running for three years. There, small annual applications of kraal manure (4,000 lb.) have greatly benefited the growth and yield of both cotton and maize. It is remarked that from the point of view of agriculture in the native areas, where ample supplies of kraal manure are possible, the large yield increases from small applications are important.

Considerable activity in the study of manuring as applied to cotton and rotation crops is shown in the reports from the Tanganyika stations. Farmyard manure, compost, crop residues and green manures are included in the materials used. The positive results attained are of a limited nature, and the uncertainties which remain are reflected in the programmes of further investigation designed. The need is the more urgent, as it is reported that natives are responding well to agricultural instruction by adopting manuring and other recommended practices.

Cultural Methods.

The importance of this subject is stressed in the Serere report, which states that "greater improvement in yield could be obtained by improved methods of cultivation than could be expected from improved selected varieties". Low yields are attributed to late planting, wide spacing and insufficient after-care. Optimum practice in these matters has been determined with considerable certainty by experiment, and the need is for more effective persuasion towards their adoption. This is no easy matter, however, and if the rate of progress and the expenditure of effort are compared for the alternative methods, some balance of advantage may remain with plant breeding.

In the Tanganyika reports the most striking results recorded in matters of cultivation indicate here also the importance of early planting, due not least to the much better quality of the lint obtained. Another outstanding indication is the advantage of ridge planting for cotton and maize especially what is described as tie-ridging, in which adjacent ridges are tied by cross ridges every three or four feet, a method which conserves rainwater and reduces erosion.

In a Domira Bay (Nyasaland) experiment ridge cultivation of cotton produced a significant increase in yield over flat, while digging gave no advantage compared with plots on which no pre-cultivation was given. The latter result which is a repetition of previous experience, tends to justify native practice in this respect. Here again all the evidence favours early planting.

Use of Compost in S. Rhodesia.

Further evidence on the effects of compost applied to cotton recorded from Gatooma makes an important addition to that collected above

on the subject of the maintenance of fertility. Applications of five tons to the acre (including a considerable admixture of soil) gave substantial increases in yield of cotton and the effect on the following maize crop was even more striking. It is suggested that the root action of vigorous cotton plants may itself contribute to the latter result in some manner not determined.

The compost is made under the working cattle of the Station with others specially kept as accessories. Indeed, it is difficult on the information given to see any essential distinction from the pen manure with which the fertility of the canefields of Barbados and other West Indian islands has long been maintained. Where the necessary numbers of cattle and the large quantities of crop residues or other vegetable material required are available, there is no basis so well proved to be capable of sustaining heavy and continuous cropping under tropical conditions.

Filling Gaps in the Stand.

Work at Barberton on what is more briefly termed in the West Indies "supplying" has produced clear-cut results of much general interest. Randomized artificial gaps amounting to 20 and 40 per cent. of the stand were filled and left open for comparison, this filling being carried out 13 and 19 days after planting. The reactions were remarkable. Response to the less crowded conditions where the gaps were left caused a marked increase in yield per plant, which did not, however, overtake the yield of the normal stand. The "supplies" were severely affected by competition with their older neighbours and their presence not only contributed little to the final yield, but, by preventing the expansion first described, had the further effect of actually reducing yield in comparison with unsupplied plots. The planting distance is not stated, though it may well be an essential factor in the results obtained. The neglect of supplying by native cultivators has been a subject for reproach. On the Barberton results the native would appear to be justified, but with the wide spacing he often adopts their application to his case is doubtful.

The Review concludes with notes summarising the work which is in progress on plant breeding, cotton diseases and insect pests.

PROPAGATION OF COFFEE BY CUTTINGS.

THE rooting of *robusta* and Conuga coffee cuttings in unheated glass frames in Java is described by P. A. Roelofsen in the *Bergcultures.** The routine method is similar to that used with *arabica* at the research stations in Tanganyika and Kenya, and therefore technique and appliances common to all are not described in this note. In Java the glass frames are covered with a white material resembling muslin, which is kept permanently moist by the leakage of water through perforations in a bamboo pipe running along the back of the frame (the lights slide under it). The pipe is fed from drums into which water is pumped as required. The moisture thus provided reduces the temperature in the frames from 95°F. to 84°F. making the difference between life and death for the cuttings. The white cover is only used on sunny days and then only from 8 a.m. to 3 p.m. Two metres above ground or 1.20 m. from the top of the frame is a lattice-work roof made of interlacing bamboo strips 19 mm. wide with 17 mm. intervals. This is supposed to admit one-quarter of the available sunlight. The essentials for success are plenty of light evenly diffused, combined with a cool temperature. The cuttings used are the upper portion of the shoots and consist of 2 or 3 joints and are 20 to 30 cm. long. Shorter cuttings usually die, as do older ones. A shoot may make two cuttings but never more. The importance of doing everything possible to guard the leaves of the cuttings from damage during transport, &c., is stressed. Damaged leaves soon fall and without leaves the cuttings will not strike. In two months the cuttings are lifted for examination and those that have rooted are planted in baskets, kept under glass a further month and then stood out in the shade. In the rainy season the extra month under glass is dispensed with. In six months from the time at which the cutting was made it should be ready for planting out. *Rhizoctonia* attack is found troublesome, especially in wet weather, but is checked by weekly Bordeaux sprays and the admission of all the light possible. Even when the cuttings are not attacked the rainy season is the more unfavourable for rooting and this is attributed entirely to the reduced light. Cuttings from fan branches grow horizontally while their root spread is also lateral. Rooted cuttings are not ready to be used as rootstocks for about a year. They can, however, be grafted at the time that the cutting is made; the successful takes (about 50 per cent.) are much lower than on rooted stocks, but the method enables clonal stock/scion combinations to be made at will and without delay. It is immaterial with coffee cuttings whether the basal cut is made above or below a joint. The application of growth hormones in water was useless and even harmful. A continuous feed of a lanolin hormone mixture maintained at the cut apex was more useful. Though not a completely efficient substitute for the removed top it was nevertheless very much more successful than the topped untreated controls, which gave particularly bad results on this occasion. There are marked clonal differences in ability to root. The necessity for studying the rootstock question is pointed out. Coffee is strongly susceptible to rootstock influence; as yet little work has been done on this question.

* 1939, **13**, 994-1002.

NYLON.

"NYLON" is considered to be one of the three or four great chemical developments of the last decade. It is the raw material for a textile-fibre, stronger and more elastic than silk, wool, linen, cotton or Rayon. Nylon is a protein-like chemical product which, although it contains the same elements as silk, namely carbon, hydrogen, oxygen and nitrogen, associated in somewhat the same way as in silk, has no exact chemical counterpart in nature. It may be described briefly as a synthetic polyamide.

Nylon had its origin in fundamental research on the synthesis of substances having long molecules of rubber-like structure. The first product was the synthetic rubber, "Neoprene" then Nylon, in the making of which dibasic organic acids and diamines are among the intermediates. The molecule is actually long enough (1/100,000 of an inch) to be seen with the aid of a powerful microscope.

Nylon is first produced as icy-white ribbons of any width and thickness that happens to be convenient for handling. If intended for use as a textile fibre, the ribbons are broken into chips. The chips are then melted, and the water-clear liquid is forced through tiny nozzles to form fine filaments which solidify in the air. These fibres are wound onto spools. At this stage, each filament is made up of chainlike, criss-crossed, molecules. To align the molecular chains into parallel formations, the filaments are then stretched. This process brings the chains so close together as to create powerful intermolecular attractions with subsequent strengthening of the filaments.

Most of the Nylon produced at the present time is used in the manufacture of yarn which, because of its high strength and elasticity, will be chiefly employed in the manufacture of fine hosiery. Nylon, however, can also be made in sheets or bars or rods, having thicknesses varying from that of a bristle to that of a man's arm. It is already on the market in the form of bristles for making tooth brushes, various other toilet brushes and certain types of industrial brushes. Nylon can also be used as an enamel, and may develop into a new and important plastic material. It is also available in the form of sewing thread, fishing lines and surgical sutures. It is said to offer numerous advantages over natural gut sutures.

The name "Nylon" is a generic word, coined by the Du Pont Company, and is not a registered name or trade mark. Because the names of two textile fibres in common use, namely cotton and Rayon, end with the letters "on", and because it appeared from the beginning that one of the principal outlets for the polyamides would be in the field of textiles, it was thought that a word ending in "on" might be desirable, so that the term "Nylon" was finally adopted.

Both Nylon and Vinyon (a synthetic resin-fibre, more like silk than Rayon, and hence usable in making hosiery to replace silk) went into production in the United States during 1939. Nylon is a Du Pont product and over eleven million dollars have already been invested in a plant for its production.

H. F. B.

RECENT DEVELOPMENTS IN THE FIELD OF SYNTHETIC RUBBER.

Although it has long been known that certain polymerization products show to a considerable extent rubber-like properties, only by a sound knowledge of the fundamentals of high polymeric chemistry and of the means by which the properties of a high polymeric compound are connected with its molecular structure, has it been possible to apply this discovery to the economical production of valuable synthetic materials. Of special importance for the properties of a high polymeric substance are :—

(1) The chemical nature of the basic material. For example, a synthetic rubber should be a hydrocarbon which guarantees the greatest resistance against the action of water, acids and alkalies ; chlorine derivatives may fulfil this requirement ; "Neoprene," one of the best synthetic rubbers of today, contains combined chlorine.

(2) The length of the chief valence chains. The main structure of all high polymeric compounds consists of long chains. Such chains must have a minimum length to give the material properties having technical importance. A polymerization degree of at least 50 is required to ensure a certain strength and resilience. As the polymerization degree is increased, the strength increases proportionately until a polymerization degree of 300-400 is reached, after which the strength reaches a constant value.

(3) The flexibility of the chains. The characteristic elasticity exhibited by natural rubber and synthetic products is basically influenced by the internal flexibility of the chains. Materials which are built up of flexible chains are, without exception, soft substances with a high degree of reversible elasticity.

(4) Cross linkage between the chains. Besides the main structure of high polymers, it is important that the chemical valence-bonds be perpendicular to the length of the main chains. Such bonds are, for instance, produced during the vulcanization of rubber, and render the molecular construction of the material stiffer and more resistant to temperature changes and abrasion.

It is these four fundamental principles that influence the technical behaviour of a high polymer, and, in order to obtain certain technical qualities in a synthetical material, they have to be closely observed, and their different influences counterbalanced. By following such a procedure, materials can be developed which have, to an amazing extent, the qualities of natural rubber.—(Abstract of Paper in *Chemistry & Industry*, Vol. LIX, No. 6, p. 89, 1940.)

H. F. B.

EXPERIMENTS ON THE CONTROL OF MANGO ANTHRACNOSE BY SPRAYING.

By R. K. McKee.
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Introduction.

Mangoes and other tropical fruits are often severely attacked by the "anthracnose" fungus, *Colletotrichum gloeosporioides* Penzig. In Trinidad and other West Indian Islands this fungus causes a leaf-spot, blossom-blight and fruit-rot, and unless it can be controlled by spraying or other means, the fruit blemishing produced is sufficient to interfere seriously with any export trade in mangoes. The blossom-blight is less serious, but may reduce the crop considerably if wet weather occurs at the time of flowering.

Colletotrichum gloeosporioides is an imperfect stage of *Glomerella cingulata* (Stoneman) Sp., and von S., but in Trinidad the perfect stage is found only in culture while the imperfect or Colletotrichum stage occurs in the field and is responsible for the spread of the disease.

Baker and Wardlaw (2) have shown that fruit is liable to infection at almost any age, although subsequent development of the fungus is postponed until the fruit is mature. It follows that if the fruit can be protected throughout the growing season by spraying, the number of infections and hence the incidence of anthracnose on ripening, will be reduced. The degree of control obtained in this way was measured experimentally in 1937, 1938 and 1939.

On untreated fruit, small black spots appear on the skin just at eating maturity; these rapidly increase in size and, if numerous, coalesce. The surface of the spot becomes sunken and may develop cracks. The flesh under these spots is softened and somewhat discoloured, the rot spreading right through the fruit in a few days. Russeting and tear-streaking, which normally involve only the skin of the fruit, are sometimes caused by the same fungus.

The latent infections of the fungus do not begin to spread until eating maturity is reached, so the loss of fruit intended for local consumption is not very serious unless infection is severe, as it can be in wet years. Late fruit which ripen in July and August, when the rains have commenced, may also be seriously damaged. In export fruit, however, any reduction in storage life or any blemishing is of much greater importance. Moreover, it has been shown by Wardlaw and Leonard (5) that, in fruit which has been stored at a low temperature (40-45°F.) and subsequently ripened, the fungus starts to develop before eating maturity is reached.

Experimental Methods and Previous Work.

In these investigations 'Julie' mango trees were sprayed with a 1 per cent. Burgundy mixture prepared in the field from concentrated solutions of bluestone and washing soda which were diluted to correct strength, mixed and promptly used. The spray was applied with a Vermorel Headland machine which could cover even the largest trees concerned. 2½-3½ gallons of spray were found sufficient for each tree.

In order to measure the benefit gained by spraying, the wastage in samples of fruit must be estimated. In 1937 the number of days elapsing between the picking of fruit when fully developed but still hard and green and the onset of blemishing and finally of wastage was noted. In 1938 and 1939 the number of days from the 'just ripe' to the 'wasted condition' was noted. A fruit was considered 'just ripe' when it first lost the hardness of the unripe fruit, and as 'wasted' when the contents had lost their firmness and become no longer marketable or edible. This method of estimation does not allow for the influence of non-fungal factors, such as seasonal conditions, on the storage behaviour of fruit. It would appear, however, from a consideration of the 'control' fruit that anthracnose is much more important than these other factors. All fruit was stored at tropical temperatures averaging about 80°F. Qualitative methods of this kind are liable to give variable results, especially from year to year, when the estimates are made by different individuals. Thus it is probable that a more severe standard of 'wastage' was applied in 1939 than in 1938. In spite of this, good agreement was obtained. The fruit normally takes some 3-3½ days to become 'just ripe' after picking in the 'full green' stage. To bring the 1937 results into line, 3½ days have been subtracted from all the data for this year (Table I). To facilitate comparison between the different years, the data are also presented as percentages.

In 1937, fruit was collected from eight trees, four of which had been sprayed weekly from flowering time in January until the fruit was harvested in May, June or July; the other four being used as controls. In all, 119 fruit from the sprayed trees and 109 from the unsprayed were examined. Baker's (1) results showed that a good control could be obtained.

In 1938, Crowdy, S. H., carried out a more elaborate experiment to determine at what time spraying was most beneficial, with a view to reducing the number of sprays. The following treatments were employed, each group consisting of four trees.

A. Sprayed for 10 consecutive weeks at beginning of season.
B. Sprayed three times around flowering time.
C. Sprayed throughout season—25 sprays.
D. No spray.
E. Burgundy } Sprayed for 15 consecutive
X. Bordeaux } weeks at the end of the season.

Ninety-one fruit were examined in Group A, 82 in Group B, 85 in Group C, 135 in Group D, and 97 in Groups E and X combined. No difference

Table I.

Days required for 20 per cent. Wastage and Percentage Improvement at Tropical Temperatures.

Treatment	1937		1938		1939	
	Days	Percentage Improvement	Days	Percentage Improvement	Days	Percentage Improvement
Unsprayed	5.8	0	5.3	0	5.7	0
2 sprays	—	—	5.5	4	6.7	18
Sprayed half season	—	—	7.2	36	7.2	26
Sprayed whole season	7.7	33	8.5	60	7.7	35

could be detected between the Burgundy and Bordeaux so these are not treated separately. The results were similar to those of 1937 but it became evident that the control of anthracnose obtained was proportional to the number of sprays applied. Slightly better control was obtained in the group which was sprayed at the end of the season than in that sprayed at the beginning, although this might well be due to the greater number of sprays applied. It was also noticed that fruit from trees which had been sprayed in the previous year were less liable to anthracnose than fruit from previously unsprayed trees, suggesting that the beneficial effect of spraying persisted for at least one year.

In 1939, similar spray schedules were tested. They were :—

A. Sprayed seven or eight times at end of season.
B. Sprayed twice at flowering time.
C. Sprayed throughout season—18 or 19 sprays.
D. Unsprayed.

Seventy-two fruit were examined in Group A, 156 in Group B, 93 in Group C and 153 in Group D. Each group consisted of seven trees, four of which had received similar treatment in the previous year, the other three being sprayed for the first time. It was hoped to measure by this method the residual effect of the previous year's spraying but unfortunately the crop on the previously unsprayed trees was both poor and late. However, a small experiment did indicate that there is probably a residual effect. The main experiment was carried out with fruit from the same trees as in the previous year, and the results of the two years' work agree well.

Discussion of Results.

In Table I a comparison of the data obtained in the three years is given. The relevant rainfall records are given in Table II. In Table I, the number of days elapsing before wastage had reached 20 per cent. is recorded for the different treatments for the different years. The percentage improvement indicates the relative improvement due to the different treatments. It will be noticed that the improvement obtained by spraying corresponds for 1937 and 1939, while a much greater relative improvement is evident in 1938, a very wet year. Fruit which has been sprayed for the whole season should in good years last two days longer than unsprayed fruit. In bad years, an increase of over three days may be expected. The increase in storage time given by smaller numbers of sprays should also be noticed. In 1939, even two sprays at flowering time, intended mainly to reduce blossom-blight, gave a noticeable improvement in storage time. Spraying for half the season is markedly beneficial.

In all three years, it was found that, while wastage in unsprayed fruit was due almost entirely to anthracnose, the wastage in sprayed fruit was due more to other causes, mainly natural senility.

Table II.

Rainfall in Inches per Month.

	1937	1938	1939
January ...	6.21	2.22	1.55
February ...	0.81	1.50	2.39
March ...	0.64	3.13	0.97
April ...	2.91	6.07	0.99
May ...	0.47	7.87	3.54
June ...	6.36	4.84	6.07
July ...	4.54	8.66	7.05

The spores of the fungus are produced on dead leaf tissues (3). Spraying, no doubt, protects the leaves from attack as well as the fruit and thus reduces the supply of spores capable of infecting fruit in any one tree. It is probable that spores are disseminated mainly in water and transfer from tree to tree is probably much less important than transfer within any one tree.

The results agree with those obtained in other countries. In discussing blossom-blight all workers stress the difficulty of control if wet weather is experienced at flowering time. West (5) even found that, in Florida, spraying 3 or 4 times at 4 day intervals around flowering time was unsuccessful in preventing serious blossom-blight if the weather was dull and showery. Sattar and Malik (4) working in the Punjab, stress the importance of destroying all diseased mango leaves and twigs, both on the tree and lying about the orchard; they found that the disease could be

controlled on young grafted trees by 3 sprays per year with 3 : 3 : 80 Bordeaux. Experiments with mature trees were not conducted. In Trinidad, twice as many fruit were set on the sprayed trees as on the unsprayed in the wet January of 1937, but, by the end of February the unsprayed trees had flowered again and set nearly as many fruit as the sprayed trees, so that the only result was an earlier crop on the sprayed trees. In 1939, slightly better setting was observed on the sprayed trees in January, but much of this fruit was shed when half grown, when a second flower flush occurred in March. However, if wet weather persists right through the flowering time, spraying undoubtedly gives an increase in amount of fruit set.

Reduction of anthracnose can be brought about by spraying, this reduction being greater in wet than in dry years. Whether or not spraying is an economic proposition depends entirely on the premium paid for clean fruit. Spraying throughout the season could hardly ever be economic. Infection studies and isolation of the fungus from fruit of various ages suggest that the young fruit is more susceptible than the mature fruit (3). Thus the most effective spraying schedule would be two sprays around flowering time, followed by occasional sprays until the fruit is half grown. This does not agree with the results of 1938 when the end of season spraying gave somewhat better control than spraying at the beginning of the season; it is suggested that in 1938 the conditions were so wet (Table II) that infection even of old fruit could take place. In 1939, it was noticed that, at the end of July, a month after spraying had been discontinued, the fruit on the unsprayed trees was much more severely attacked than it had been a month previously, while there was little difference in the quality of the sprayed fruit. This indicates the increased incidence of infection in the wet season, and it is probable that late fruit would be much improved in quality by spraying.

On some fruit, rough brown surface scabs were found, usually where a drop of spray had dried. They were probably due to direct spray injury, which can be caused by the use of too strong or incorrectly mixed solutions and is most severe in dull cloudy weather. The cause was not ascertained in this instance. It was also noticed that snow scale was more plentiful on the sprayed than on the unsprayed trees. In countries such as Trinidad, where scale insects are plentiful and where natural control is by entomogenous fungi, spraying with copper sprays, by reducing these fungi, allows the scale population to increase more rapidly than it would otherwise have done. To prevent this, some spray containing oil, such as Bordeaux or Burgundy-oil mixture, should be employed.

In 1939, it was noticed that pruning the tree had a marked effect on the storage quality of the fruit. Two of the control trees had been thinned, the other two were thick and bushy. The fruit from the open pruned trees not only kept better than that from the bushy trees but it had also a more brightly coloured and attractive appearance. It is possible that many mango trees would be similarly improved by pruning.

Summary.

1. A spraying trial for the control of mango anthracnose which was carried out for three years is described.

2. Results show that good control is obtained by spraying with a 1 per cent. Burgundy mixture. Spray schedules are discussed.

3. It is suggested that spraying in any one year continues to give a beneficial effect in the next year.

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CLOVE CULTIVATION.

Mr. L. G. T. Wigg's account of clove cultivation in Zanzibar published by the Department of Agriculture (pp. 63, price 5*s*.), contains many points of practical interest particularly to local cultivators of this plant. Certain cultural instructions dealing with the nursery may be noted. In raising young plants the seed should be obtained from trees of known high yield, though it is not yet certain to what extent such characters are inherited. It seems likely, however, that the clove can be self-fertilized and if the buds are picked early from the trees surrounding the parent the chances of a pure strain are increased, though cross-fertilization by distant wind- and insect-borne pollen would still be possible. The inferiority of self-sown seedlings compared with nursery-grown seedlings as planting material is emphasized and the different root systems of the two are illustrated. Good seeds should be a fresh olive green with little or no red, should weigh less than 500 seeds to the lb. and be free from insect damage. The radicle tips should not be blackened and the seed should be obtained from single-seeded fruits. The number of good seed to be expected from 1,000 fruits is about 450. Up to 96 per cent. germination is obtainable from properly selected seed. The clove seed must not be buried in the soil when sown but must be placed in open drills, radicle downwards, and covered with loose leaf litter to maintain moisture. Transplanting is done at the age of from 12-17 months. The plants should be lifted with a ball of soil wrapped in banana leaf, possibly a month in advance and stood close together in trays; a new and very fibrous root system will have resulted by planting time.

AIR TRANSPORT, INSECTS AND DISEASE.

Mr. F. G. Sarel Whitfield has recently issued a comprehensive article on air transport, insects and disease (*Bull. Entomol. Res.*, 30, 365-442; 1939). The discovery by Shannon in 1930 of the presence of *Anopheles gambiae*, an insect native to Africa, in the city of Natal, Brazil, and its subsequent spread, directed special attention to the carriage of disease-bearing insects by aeroplanes. Whether *A. gambiae* was actually transported in a surface vessel or in an aircraft will probably never be known, but, as the result of its entry and subsequent spread, more than 90 per cent. of the population around Natal were infected with malaria in 1938. The indexes of malaria-infected mosquitoes are said to be the highest in the history of malaria. The introduction of *A. gambiae* into South America seems to have had the disquieting results, just referred to, because possibly the native population has very little power of resistance to the African strain of the disease carried by the mosquito.

The situation as regards yellow fever is potentially far more serious than that concerning malaria. Shannon, Whitman and Franca in 1938 made a significant contribution to what is known of the vectors of yellow fever. They produced positive evidence of the mosquitoes *Aëdes leucocelaenus* and *Haemogogus capricorni* being concerned in the transmission of jungle yellow fever in Brazil. Until this discovery, evidence of any mosquito other than *Aëdes aegypti* being implicated in the transmission of yellow fever was furnished solely on the results of laboratory experimentation. The aspect of most importance with regard to aerial transport, arising out of recent research on yellow fever epidemiology, seems to be the discovery of vast areas in Africa and South America where the disease prevails in epidemic or endemic form. It is obviously of prime importance that aircraft operating within and from Africa and South America should be maintained free from all insects. Mr. Whitfield points out that the proposed reserve Empire war route across Africa to India and Australia will present an urgent problem in this connexion, and that it would be unwise to inaugurate such a service until the proper control of insects in aircraft has been achieved. In view also of the proved existence of considerable insect populations in the upper air, the question of the possibility of aircraft collecting insects while in flight arises. The ability of insects to survive air transit is another problem. *Aëdes aegypti*, for example, has been proved to be able to endure a journey of at least 9,580 miles in length and of 6½ days duration.

Diptera are overwhelmingly the commonest insects found in aircraft. Species of *Musca* are very frequent and also many kinds of mosquitoes. The control of insects in aircraft is a difficult subject. As Mr. Whitfield remarks, it involves the co-operation of the entomologist, the chemist and the engineer, an airline operating company and a commercial aircraft manufacturer. Such joint approach to the problem, he holds, is essential if progress is to be made. No adequate and reliable methods of control of insects in aircraft has yet been devised; the problem of controlling insect invaders of aerodromes needs also the fullest attention. Little will be gained, the author adds, from further research upon insects found in aircraft—the real problem being the effective means for their destruction.—(A. D. Imms, *Nature*, Vol. CXLV, No. 3663, p. 76, 1940.)

VITAMIN CONTENTS OF SOME FOODS USED IN THE B.W.I.

The following is a short list of the chief vitamins present in certain of the commoner food materials consumed by residents in the British West Indies, such as are available in season at relatively small cost:—

Coconut Oil	A	—	E		—	—
Maize	A	D	E		—	—
Rice	—	—	—		B1	—
Dried Peas	A	—	—		B1	B2 —
Potato	A	—	—		—	C
Sweet Potato	A	—	—	B		—
Banana	A	—	E		B1	B2 C
Breadfruit	A	—	—	B		—
Grapefruit	A	—	—	B		C
Lettuce	—	—	E	—		—
Mango	A	—	—	—		C
Orange	—	—	—	B	B1	B2 —
Papaw	A	—	—	B		C
Tomato	A	—	—	B	B1	B2 C
Egg	A	D	E		B1	B2
Condensed Milk	A	—	—	B	B1	C

The only vitamin which is scarce in these foods is vitamin D which is found almost exclusively in fish oils, although egg-yolk is also a very rich source. Eggs and fish-oil preparations are perhaps a luxury to the native peoples, so that their diets are probably altogether deficient in vitamin D, a deficiency said to be the most important dietetic defect at present known.

It seems that it is a mistake to ascribe poor health in a community entirely to vitamin deficiency in the foods available. Even a cheap unvaried diet of bananas, maize, rice and grapefruit would supply all the required vitamins, and it is more than likely that ill-health and under-nourishment are due, not so much to lack of vitamins, as the preponderance of one type of food in the diet and the deficiency of another. Carbohydrate and protein metabolism go hand in hand, but, if there is a lack of meat or fish or other protein foods in the diet, all the carbohydrates and vitamins in the world cannot build up tissue and muscle. It has, moreover, been found quite definitely that overloading the diet with carbohydrates is a contributory factor to the development of rickets, or in other words, although lack of vitamin D is the specific cause of rickets, a constant feature of rickets-producing diets is an excess of carbohydrate.

H. F. B.

CONTROL OF COTTON STAINERS IN THE WEST INDIES.

THE two most serious pests of cotton in the British West Indies—the Pink Bollworm and the Cotton Stainers of the genus *Dysdercus*—have been brought under control to a considerable extent by the enforcement of a close season of 2½ to 3½ months. The problem is complicated by the ability of the Pink Bollworm to survive this host-free period in a dormant state, and by the occurrence of wild hosts on which the Stainers can breed in large numbers. The eradication of these alternative food-plants has proved successful in many cases, but some further work is required. The relation between the numbers of the Stainers and their host-plants is the main subject of a recent interesting paper by F. A. Squire ("Observations on Cotton Stainers in the West Indies", *Bull. Ent. Res.*, **30**, 3, 289-92, 1939). The following is a summary of his most important results.

Cotton Stainers can feed on a large variety of plants, but it is only when ripening or ripe fruits are present that they breed and multiply extensively. Throughout the British West Indies four species of wild plants other than cultivated cotton are of special importance. Two wild cottons (*Gossypium purpurascens* and *G. religiosum*) have been practically eradicated in the cotton-growing islands. The Seaside Mahoe (*Thespesia populnea*) fruits perennially and can maintain a permanent infestation; in Montserrat the eradication of this host alone proved a successful control. The Silk Cotton (*Ceiba pentandra*), the most widely distributed and best known of Stainer hosts, fruits erratically and may support Stainers for periods as long as six months.

In St. Vincent the eradication of *Ceiba* and *Thespesia* has suppressed the Stainers in the greater part of the island, but they are still a formidable pest in the Carib country. Squire shows that a complete cycle of hosts in the fruiting stage is provided by *Sterculia caribaea* and the Kola Nut (*Cola* sp., probably *acuminata*). The former is a mountain forest tree, which flowers in March or April and by December supports a vast Stainer population. The Kola Nut was introduced from West Africa some fifty years ago, but failed as an economic crop. It frequents humid valleys, fruiting from June to September. The extermination of these two plants has been undertaken and it is hoped that the cycle of hosts may thus be broken and control of the Stainers established throughout St. Vincent.

A. M. A.

MISCELLANEOUS NOTES.

Research on Fodder Crops in Palestine.

The report of the Acting Director of Agriculture for the period January to June, 1939, contains the following notes on research work on fodders carried out by the Palestine Department of Agriculture and by grant-aided and other institutions in that country.

The group experiment testing the economic maintenance of milch cows on a high ration of green forage has been continued in the barn with good results. By diversifying with the new green forages mentioned it has been found possible to increase the participation of green roughage to 95 per cent. of the total winter feed ration while maintaining a milk production rate of 15 kilogrammes per head per day. At the same time it has been possible to replace sunflower and peanut cakes in the ration with farm-grown legume grain concentrates.

Pit silage experiments with a view to the economic provision of legume feeds for the summer season have been carried out. With mixtures of horse-bean and non-legume feeds such as oats, barley, orange or grapefruit, promising results have been recorded. A large-scale silage experiment was conducted this year also with whole orange culls. This material gave a good silage feed, but some loss of juice was noted. Experiments on the ensilage of potato foliage and stock-beet mixtures are under way.

Digestibility experiments with sheep were carried out during the period under review with carob pod, ground carob bean, orange fruit, and local legumes known as kersenna (*Lathyrus* sp.) and jilbana (*Vicia sativa*). The latter two were found to be rich in protein, rating 20 per cent. of this constituent. The excellent feeding value of oranges was confirmed.

Experiments are being carried out at the Daniel Sieff Research Institute, Rehovot, on carob seeds and the fermentation of carob meal. At the present juncture it appears to be too early to submit any definite results.

Field experiments conducted by the Plant Protection Service of the Department for the control of the larvae of the moth *Prodenia litura* Boisd. by the use of a sodium or barium fluosilicate bran bait in the proportion of 10 to 1 by weight have given satisfactory results. Water must be added in sufficient quantity to moisten the bait.—(*Bull. of the Imperial Inst.*, Vol. XXXVII, No. 4, pp. 572-73, 1939.)

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Composts in Ceylon Tea Estates.

Under aerobic conditions, materials such as straw, Gliricidia and weeds, develop mucilaginous substances readily, and the quantity increases with increase in the pH value of the compost. Owing to the presence of tannin, refuse tea and tea leaf-prunings produce little or none of these substances regardless of the pH value, and similar results are obtained when decomposing Gliricidia is kept moist with an aqueous extract of tea leaf, instead of plain water. The presence of tannin also completely inhibits formation of ammonium salts and nitrites during the aerobic fermentation of tea leaf, whereas a considerable portion of the nitrogen in green manures is converted into these forms. The pH values of sixty-nine samples of various types of compost ranged from 6.0 to 8.0 and higher. — (T. Eden, *Chemical Abstracts*, Vol. XXXIV, No. 2, 1940.)

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Determination of Starch.

Chinoy (*Analyst*) has proposed a new iodine method for the determination of starch, applied particularly to leaf material; this is extracted with 80 per cent. alcohol to remove soluble carbohydrates, &c., and it is then suspended with 0.7 per cent. potassium hydroxide solution in the presence of purified sand. The extraction is repeated as necessary, and the extracts are concentrated and neutralised with 10 per cent. acetic acid. The determination is then carried out as starch iodide, and duplicates only vary within 1-2 per cent.; added starch to starch-free material was recovered 96-98 per cent. Values given by hydrolysis method are usually higher than by the starch-iodide method—this is thought to be due to the fact that the hydrolytic methods do not give values of "true" starch. An interesting observation from this paper was that leaf samples taken in the evening all show increases in the starch content over the corresponding morning samples. A subsequent publication by the same worker (*Analyst Abstracts*) has described a colorimetric determination of starch applicable to the determination of potato, rice and wheat starches. The iodine is generated gradually in the solution containing starch, in which case the starch iodide is not precipitated but remains as a blue colloidal solution. This is effected by liberating the iodine in a neutral or weakly acid solution by adding 2-3 ml. of *N*. KI and 1-2 ml. of 3 per cent. H_2O_2. After one hour, the excess of iodine is extracted by chloroform. The blue colours can then be matched in a colorimeter; as little as 0-5 mg. of starch can be determined, it is said, with an error of 2-3 per cent.—(*Food*, Vol. 9, No. 101, p. 109, 1940.)

* * *

Decomposition of Organic Matter in Soil. *By R. S. Dyal, F. B. Smith and R. V. Allison.*

A study was made of the decomposition of green Crotalaria and green Natal Grass harvested at two different stages of growth in Norfolk Loamy-Fine Sand of varying degrees of acidity from pH 3.71 to pH 7.05. All plant materials decomposed more rapidly and more completely in soils at pH 5.94 to pH 7.05 than at pH 3.71 to pH 4.59. The detrimental effect of acidity on decomposition was more pronounced in soils treated with Natal Grass than in soils treated with Crotalaria. The acidity of the soils treated with Crotalaria was decreased markedly in the soils at low pH in the beginning of the experiment. The addition of nitrogen as potassium nitrate to the Natal Grass-treated soils, in an amount sufficient to bring the total nitrogen content of these soils to that of Crotalaria-treated soils, did not increase the decomposition of the Natal Grass. Decreased nitrification in the soils at pH 3.71, pH 4.26 and pH 4.59 was undoubtedly brought about by the micro-organisms utilizing the ammonia in the decomposition of the carbonaceous materials, and also partly by the detrimental effect of the increased acidity on the nitrifying bacteria. A deficiency of available calcium in the strongly acidic soils could possibly have caused this decreased nitrification observed in the soils of low pH value. Plant materials containing large percentages of hemicellulose, cellulose and lignin fractions decomposed more slowly than those containing smaller percentages of these constitutents.—(*Chemical Abstracts*, Vol. XXXIV, No. 2, 1940.)

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Early Manurial Needs of Sugar-cane. *By H. Evans.*

Cores were removed from the middle inter-nodes of cane cuttings by means of a cork-borer, the holes filled with a mixture of equal parts of urea and potassium phosphate, sealed with cork stoppers, and the cuttings grown in moist sawdust for three months. As compared to the controls, the treated cuttings produced more shoots and showed much better growth of shoots and roots. Also the leaves and stems of shoots from the treated cuttings showed higher percentages of nitrogen, phosphorus and potassium in the dry matter than did those from the controls. In field experiments, internally-treated cuttings gave better results than did either the controls or the cuttings that received the same quantity of fertilizer mixture placed in the ground outside the cuttings. Ammonium salts had a marked toxic effect when they were placed in the cuttings.—(*Chemical Abstracts*, Vol. XXXIV, No. 3, Col. 843, 1940.)

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Toxicity of Selenium-containing Plants to Pests.

Among papers read before the annual meeting of the American Association for the Advancement of Science, which took place at Columbus (Ohio) at the end of December last, are two on the above subject. V. H. Morris, C. R. Neiswander and J. D. Sayre discussed a method of rendering corn plants resistant to red spider attacks by growing them in nutrient solution to which was added each week 1 p.p.m. of sodium selenate. When the rate of selenium application was increased to two or three p.p.m., no red spiders were found to survive. Under such conditions, the growth and normal nutrition of the plants were unaffected. Similar results have been obtained in additional tests with a number of other species of plants. In the second communication, Messrs. Neiswander and Morris described results of experiments indicating that an accumulation of 90 to 100 parts per million of selenium in the tissues of certain plants was sufficient to prevent infestation by the common spider, *Tetranychus telarius*, and that a lesser amount controlled the chrysanthemum aphid *Macrosiphoniella sanborni*. The investigation suggests a possible method for controlling pests of ornamental plants.—(*Nature*, Vol. CXLV, No. 3672, p. 430, 1940.)